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Corresponding Author: Dr. Jordi Bartolomé, Ph.D.

Corresponding Author's Institution: Universitat Autònoma de Barcelona

First Author: Leidy Rivera-Sánchez, Master Science

Order of Authors: Leidy Rivera-Sánchez, Master Science; Jorge Cassinello, Ph.D.; Elena Baraza, Ph.D.; Jordi Bartolomé, Ph.D.

Abstract: The aim of this study was to compare the trophic behaviour and the social structure of Majorcan wild goats and feral goats present in the island of Majorca. The former are descendants of an ancestral goat ecotype introduced in the island in the late Neolithic, whereas feral goats come from domestic forms introduced recently from the Iberian Peninsula. The study was conducted in four localities of the Serra de Tramuntana, a mountain range located in the northwest of the island of Majorca. Behavioural data were collected in three seasons, summer, winter and spring of 2011-2013, and when goat activity is at its peak, i.e., three hours after dawn and before dusk. The following variables were recorded: group composition (males, females, and kids) and activity (feeding, walking, resting, and watching). The proportion of time spent on each activity and their frequency were obtained from focal samples. Multivariate analyses of variance (MANOVA) were used to simultaneously analyse the activity variables. A total of 155 observations of 85 herds were registered throughout the study. A similar behaviour pattern has been observed in this study for the two goat ecotypes, feral and wild, apart from some seasonal variations in feeding and resting activities. In summer, feral goats showed higher feeding efforts (duration and frequency) than wild goats; this might be related to a lower efficiency obtaining feeding resources by the former, whereas wild goats, that have inhabited the island for millennia, coexisting with vegetation in periods of lower forage abundance and quality, would be more efficient herbivores during restrictive periods. Average herd size for both ecotypes is smaller than that recorded for domestic goat herds, suggesting a relatively low browsing damage compared to the latter. Also, feral goats apparently have a higher gregarious behaviour than wild ones, which might relate to their domestic origin. Currently, the management of goats on the island is based on maintaining the wild ecotype and eradicate the feral one, whose impact on vegetation is supposedly worse. However, our results show a similar trophic behaviour by both ecotypes, so that their impact on vegetation should also be expected to be similar, indicating that this argument has not enough scientific basis.

Comparative study of trophic behaviour and herd structure in wild and feral goats living in a Mediterranean island: management implications

Rivera-Sánchez Leidy[1]

Cassinello Roldán Jorge[2]

Baraza Ruíz Elena[3]

Bartolomé Filella Jordi[1]

[1]Department of Animal and Food Science. Universitat Autònoma de Barcelona, 08193 Bellaterra (Spain)

[2]Departament de Biologia, Universitat de les Illes Balears, Cta de Valldemossa km 7.5, 07122 Palma de Mayorca (Spain)

[3]Instituto de Investigación en Recursos Cinegéticos (IREC), Ronda de Toledo s/n 13071 Ciudad Real (Spain)

Corresponding author

Bartolomé Filella Jordi

Department of Animal and Food Science. Universitat Autònoma de Barcelona, 08193 Bellaterra (Spain). Tf. (34) 93 5811496, Fax: (34) 93 5811494

e-mail: jordi.bartolome@uab.cat

Abstract

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similar trophic behaviour by both ecotypes, so that their impact on vegetation should also be expected to be similar, indicating that this argument has not enough scientific basis.

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1. Introduction

The arrival of goats (*Capra* sp.) to the island of Majorca is very ancient, and has documented between 2300 and 2050 BC during the Pre-Talaiotic culture (Seguí *et al.*, 2005). It has been postulated that the first goats introduced to the island gave rise to a local breed that remained in the wild until present, the so-called Majorcan wild goat (*Capra aegagrus [hircus]* ssp.). Currently, it is an important source of income through hunting activities in the island (Seguí *et al.*, 2005), being in the hunting grounds where the purest populations are conserved. The introduction of domestic breeds (*C. hircus*) in more recent times and their subsequent abandonment has led to the establishment of a large population of feral goats phenotypically clearly differentiated (Vives and Baraza, 2010). This abandonment took place in the 1960's, when tourism began to develop intensively. Goats may form feral populations in localities where they are abandoned, as keeping them as domestic stock is no longer valuable, and particularly where predators are absent or scarce (Parkes *et al.*, 1996), as it occurs in Majorca.

Herds of feral goats have a marked effect on the ecosystems they inhabit (Coblentz, 1978) and can be an economic and hunting resource (Forsyth *et al.*, 2009). In many places the feral goat is considered an invasive species (Parkes, 1993; Parkes *et al.*, 2002), foreign to the natural ecosystem and therefore its eradication is recommended in order to reduce the negative impact on the agricultural and natural ecosystems.

In the Serra de Tramuntana of Majorca, feral goats have been present for at least 50 years, according to farmers' accounts. In the past, both wild and feral goats were hunted alike on the island using an ancient technique called "cans i llaç" (dogs and loop), which consisted of a round up the goats with the help of dogs in cliffs and then catching them with a loop (Seguí, 2014). Nowadays, the way that goats are managed in the island differs according to their ecotype. Wild goats are only hunted using firearms it hunting areas, whereas feral goats are captured throughout the highlands using both techniques, dog and loop for kids, and firearms, in eradication campaigns.

The available literature on the behaviour of goats describes a very similar social behaviour between wild and feral populations (Shackleton and Shank, 1984). Therefore, we would not expect much difference between the behaviour of feral goats and the Majorcan wild goats, but due to different handling both ecotypes receive, their behaviour could be different. The main objective of this study was to compare the trophic behaviour and the social structure of Majorcan wild goat and feral goat herds present in the island of Majorca. The identification of food habits and routines, as well as the social structure of both ecotypes, might allow us to establish proper management scenarios for both goat ecotypes.

2. Methodology

2.1. Study area

The study was conducted in four localities of the Serra de Tramuntana, a mountain range located in the northwest of the island of Majorca. It ranges 90 km and stretches in a southwest-northeast direction, with a surface of 800 km^2. The highest peak is Puig Major, 1,445 m above sea level (a.s.l.) (39° 48′ 27″ N, 2° 47′ 36″ E). The entire mountain range was listed as a World Heritage Site by UNESCO in 2011.

The climate is typically Mediterranean, with two rainy seasons (spring and autumn), a hot dry summer and a warm dry winter. Spatial variation of rainfall is significant, with a maximum of 1400-1600 mm per year located in the central sector of the mountain, with drier points not exceeding 300-350mm in coastal areas. The annual average temperature ranges from 16 to 18 º C in the lower parts of the mountain. The four areas considered in this study are located in the lower part of the mountain range between 77 m and 439 m. a.s.l. The perennial tussock grass *Ampelodesmos mauritanica* dominates the vegetation community. Several shrub species, such as *Chamaerops humilis*, *Olea europaea* var. *sylvestris*,or *Pistacia lentiscus* are scattered over the territory, mainly close to caves and rock shelters. This plant community is characteristic of the giant reed thicket succession (*Smilaco balearicae-Ampelodesmetum mauritanicae*), according to Rivas-Martínez *et al.* (1992).

Two study areas, Formentor and Victoria (Figure 1), are hunting estates where animals are selected according the breed traits of the Majorcan wild goat (Decree 91/2006 of the Council of Majorca). The animals survive year round with the resources of the estates, without any food supplementation, but subject to disease control. The stocking rate of these areas was calculated from data provided by the managers (Figure 1). These goats are considered as *Capra aegagrus* by some authors, because of their wild status (Seguí and Payeras, 2002; Masseti, 2009), but some others argue that they are feral populations of ancient domestic stocks, and should be included in the domestic species *Capra hircus* (Giannatos *et al.*, 2006). The other two study areas have been occupied for decades by feral domestic goats (Figure 1). These animals are not subject to any form of management, except by some sporadic attempts to control populations by the island authorities. In that case, the stocking rate was estimated from field observations.

141 2.2. Data collection

142

143 Data were collected in three seasons, summer, winter and spring of 2011-2013. An
144 observation point was assigned to each one of the four study sites, with ample
145 visibility of areas usually used by goats. Data were collected 3 hours after dawn or
146 before dusk, when goat activity is at its peak, as usually happens in other ungulates
147 (e.g. Carranza *et al.*, 1991; Cassinello, 2000).

148

149 When a goat herd was sighted, group composition and age-sex clases (number of
150 adult males and females, and kids) were registered. Behavioural data of adult males
151 and females were collected following the methodology established by Altmann
152 (1974) and Martin and Bateson (1986). It consisted in a series of focal samples
153 where the behaviour of a given individual was registered in a paper sheet. Focals
154 were 15 minutes long, and allowed the continuous recording of individuals' activity,
155 i.e., feeding, walking, resting and watching. Both duration and frequency of
156 behaviours were thus estimated. In order to minimize the possiblity of recording the
157 same individual or herd more than once, we alternated our visits to the different
158 observation points.

159

160 2.3. Statistical analysis

161

162 The proportion of time spent on each activity and their frequency were obtained from
163 focal samples. Spearman correlation analyses of the response variables (feeding,
164 walking, watching, and rest) were estimated. Because the lack of normality of data
165 (Shapiro-Wilk test, $P < 0.05$), the square root transformations + 0.5, arcsine of the
166 square root, and logarithm plus one were applied to frequencies, proportions, and
167 absolute values, respectively. To reduce the effect of sampling area, the
168 standardised values of variables (Z values) as regards the sampling area were

169 calculated. Multivariate analyses of variance (MANOVA) were used to
170 simultaneously analyse four dependent variables: feeding, walking, watching, and
171 resting. The independent variables considered in the model were season, ecotype,
172 and sex. The Roy's Max Root test was used to estimate the significance of the effect
173 in the MANOVA. Furthermore, for those variables showing significant differences,
174 one-way and two-way factorial ANOVA were performed, and least square means of
175 the levels estimated.
176
177 To analyse the observed frequency of encounter of the different herd types in the two
178 ecotypes of goats, a Chi squared test was used. Moreover, the herd size,
179 transformed with logarithm plus one, was evaluated by ANOVA, taking into account
180 the effects of season, type herd, and goat ecotype. The mean differences between
181 levels of factors included in this analysis were evaluated by least squares. Statistical
182 analyses were performed with JMP statistical software, version 8.0 (JMP 8.0 SAS
183 Institute, 2008).
184
185 **3. Results**
186
187 A total of 155 observations were taken throughout the study. A significant difference
188 was obtained between proportion variables (Table 1).
189
190 The MANOVA analysis of the proportions and frequencies showed that the
191 interaction between season and goat ecotype was significantly related to the
192 behaviours observed (Table 2). The walking and watching variables had no
193 significant differences, showing a mean of 16.9 ± 1 and 14.8 ± 1.3 for percentage
194 and 0.7 ± 0.04 and 0.5 ± 0.03 for frequency, respectively.
195

196 Our results showed that the percentage of time devoted to feeding by both ecotypes
197 was lower in spring than in winter and summer ($F_{(5.138)} = 2.93$, $P = 0.01$); however,
198 the feral domestic goats devoted more time to feeding in summer than the Majorcan
199 wild goat, Figure 2 (LS Mean Differences Student *t*).
200
201 As regards feeding frequency (Figure 3), the Majorcan wild goat showed a higher
202 frequency in winter than in spring and summer ($F_{(5.138)} = 3.50$, $P = 0.005$), while the
203 feral domestic goats did not show significant differences for this trait. Differences
204 between ecotypes were only found in summer, when feral goats showed a higher
205 feeding frequency than wild ones.
206
207 It was observed that the resting frequency for both goat ecotypes was higher in
208 spring than in winter and summer; however, in winter feral domestic goat resting
209 frequency was greater than that of the Majorcan wild goat ($F_{(5.138)} = 4.16$. $P = 0.001$;
210 Figure 4).
211
212 A total of 85 herds were observed during the study. Out of these, 37 corresponded to
213 feral goat herds and 48 were wild goat herds. The observed herds were grouped into
214 three categories: mixed (herds made up of males, females and kids), males (herds
215 composed only by males), and females (herds made up of females with or without
216 kids). The Chi squared test for herd type showed differences in the proportion of herd
217 type sightings ($X^2_{(7,81)}=70.39$, d.f.=3. $P<0.0001$). In the case of wild goats, it was
218 observed that the frequency of finding mixed herds was greater than that of female
219 and male herds, respectively ($P<0.05$). As for feral goats, the frequency of finding
220 either mixed herds or female herds was higher than that of male herds ($P<0.05$,
221 Figure 5a).
222
223 The size of the herds is shown in Figure 5b. Mixed and female herds were larger in

feral than in wild goats (P<0.05), whereas the opposite occurs with male herds, which were significantly larger in wild (P<0.05).

4. Discussion

This study undertakes for the first time a comparative study of trophic behaviour and herd structure of two goat ecotypes inhabiting the island of Majorca; i.e., feral goats introduced in recent times and Majorcan wild goats, the descendants of an ancestral goat which was introduced to the island more than 4000 years ago (Seguí et al., 2005). Subtle differences between both ecotypes are reported, but we conclude that their effects on the ecosystem should be similar.

4.1. Activity patterns

Our results have revealed that during their peak activity goats devote most of the time feeding, as it has been reported in other goat populations (Askins and Turner, 1972). It is also expected that goats spend the longest feeding time when in shrublands, due to their small bite size and the fact that leaves are spread out between and within the branches (Kenney and Black, 1984).

Feeding time was inversely related to the time devoted to other activities, and was also affected by season. Both goat ecotypes spent more time feeding in summer and winter than in spring. This difference could be associated to the low quality of forage during these periods, along with an increase of energy requirements in order to maintain their body temperature regulation (Alados, 1986; Alados and Escós, 1987). The reduction of the sunlight period during winter would also determine an increase of feeding time (Valentine, 1990). In addition, in summer goats showed a relatively

252 high activity period at midday, probably due to the decrease of disturbances caused
253 by tourists, hunters and mountain trackers (personal observation). During their peak
254 activity period feral goat feeding time and frequency were higher than those of wild
255 goats in summer. This fact might be related to a lesser efficiency by feral goats in the
256 use of vegetation during this restricted season, compared to that of wild goats, which
257 have inhabited the island for millennia, coexisting with vegetation in periods of lower
258 forage abundance and quality (Pérez-Obiol, 2003; Seguí et al., 2005; Bartolomé et
259 al., 2014).
260
261 Despite walking time being inversely related to feeding time, this trend was not
262 observed for walking frequency. In fact, walking frequency showed a positive
263 correlation with feeding time, and could be explained because walking activity is
264 fundamentally related to browsing, when goats have short walks in order to locate
265 new feed sources (Arnold and Dudzinski, 1978).
266
267 Moreover, both walking time and frequency were directly related to watching time.
268 This is expected because when goats are in motion they are more visible to potential
269 threats like hunters, dogs or even tourists. No differences between the two goat
270 ecotypes were observed for watching activity, despite one of the ecotypes is subject
271 to a higher hunting pressure, as wild goats are hunted for recreational purposes, and
272 feral goats following eradication programs, that allows them to be culled throughout
273 all the year (Mayol, 2013).
274
275 Animals tend to be lying down during resting time. Time devoting to resting was the
276 least observed behaviour during the peak activity periods, as expected. Resting
277 frequency depended on the season of the year, with the highest resting frequencies
278 being observed during spring, precisely when feeding duration and frequency show
279 the lowest values, probably because of the superior forage quality characteristic of

this season. Animals ruminate while resting, therefore it is expected that goats spend additional time in spring for rumination while spending less time feeding. Conversely, during winter and summer, both goat ecotypes rested less time and less frequently, in agreement with reports by other authors (Arnold and Dudzinski, 1978), who proposed that animals reduce their resting time at relatively high or low temperatures; however our data were exclusively registered during goats' peak activity periods so that conclusions are not definitive on this issue. Feral goats resting time is similar to that of wild goats, but is less frequent, and is a more frequent behaviour in domestic goats (Shackleton and Shank, 1984). The fact that wild goats have shorter resting periods than feral or domestic goats could be associated with the wildness degree.

4.2. Structure of herds

The structure of herds observed in both goat ecotypes in the Serra de Tramuntana of Majorca follows the pattern reported for other feral goat populations (Parkes, 1984; Shi *et al.*, 2005), as well as the one usually observed in other wild goat populations (Shaller, 1977). The basic social unit is generally an adult female and her offspring, which associate with similar groups in a given area (O'Brien, 1988). The average herd size in this study was higher than that reported in other goat populations (Granados, 2001; Suances, 2010), although we found clear differences between both goat ecotypes.

Females and mixed herds were larger in feral goats than in wild ones, which is in agreement with the expected higher gregariousness characteristic of domestic ungulates (Shackleton and Shank, 1984). However, feral male herds were significantly smaller than those of wild goats. This is probably as a result of ancient domestication processes, which has been postulated to lead to a certain sedentary

308 behaviour, so that migrating bachelor male groups tend to disappear (Martínez *et al.*,
309 2014).
310
311 In this study, feral goats showed variations in herd size across the year, as reported
312 previously by Shi *et al.* (2005) and Suances (2010), being greater in summer and
313 winter. Gregariousness is a condition that allows information to be transmitted within
314 herds (Wilson *et al.*, 1975), a condition quite frequently reported in feral goats. Goats
315 tend to follow older individuals in periods of food shortages and higher drought, as
316 the location of better food and water sources can be transmitted from older
317 individuals to younger ones (O'Brien, 1988). This could be an explanation for the
318 increased size of the study feral goat herds in summer and winter. On the contrary,
319 herds of wild goats had similar sizes throughout the year. As mentioned previously, it
320 is likely that wild goats are more efficient in searching for food in less favourable
321 seasons. This appears to be reinforced by the vegetation management in hunting
322 estates, where burning and clearing are applied occasionally for improving forage
323 quality. Other studies have observed a constant herd size during the year of goats
324 living on islands in favourable conditions (Shackleton and Shank, 1984).
325
326 4.3. Management implication
327
328 Our study may give some clues to understand the comparative behaviour of feral and
329 wild goats in islands. There has been a tendency in the island of Majorca to keep
330 native wild goats, whereas to eradicate feral populations on the grounds that the
331 latter causes severe damage to vegetation. However, and according to this study,
332 both goat ecotypes have a very similar trophic behaviour, so that their impact on
333 vegetation should be expected to be similar. The slight differences observed may
334 suggest that wild goats are better adapted to the plant community present on the
335 island.

Our data suggest that feral goat populations, which originally came from domestic stocks, maintain certain social structures that resemble their domestic origin, such as a relatively high level of gregariousness, athough average herd sizes of both wild and feral goats in the island are lower than the average size reported for domestic goat herds. Herbivore large herds, as it is usually the case of livestock, are likely to have severe impacts on vegetation (Orueta, 2003), especially in habitats with no history of intense herbivory; whereas herbivory caused by small herds is usually beneficial (see, e.g., Anderson *et al*. 2007). However, in an island where herbivore ungulates have been around since before the arrival of man, as it is the case of Majorca (Alcover *et al.*, 1999), endemic plant species have been subjected to browsing and have evolved with the presence of these herbivores.

Browsing signals have traditionally been seen as detrimental for environmental conservation if they are related to overgrazing, desertification, and their consequent contribution to climate change and loss of biodiversity (Mancilla-Leytón, 2014). However, goat browsing behaviour, when in moderate intensity, has been shown to maintain and enrich plant communities, particularly in comparison with other domestic ungulates. High food selection and a strong preference for browsing enable goats to reduce the variation of energy and protein in their diet caused by environmental or management conditions (Fedele *et al.*, 1993). Moreover, because of this versatility of grazing/browsing behaviour, goats are able to effectively control invasive plant species, while at the same time select a diet that meets their nutritional requirements (Mancilla-Leytón *et al.*, 2013). However, as an increase of both wild and feral goat populations in the study area may cause serious damage to vegetation, the practice of traditional hunting with dog and loop might help to regulate feral goat populations. This is why we would suggest preserving, or even promoting, this type of ancestral hunting in Majorca.

364

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366

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371

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Figure captions

Figure 1. Sample location

Figure 2. Proportion of time devoted to feeding for goat ecotype and season (values are mean ± SE).

Figure 3. Feeding rate for goat ecotype and season (values are mean ± SE).

Figure 4. Resting rate for goat ecotype and season (values are mean ± SE).

Figure 5. (a) Herd type size for goat ecotype, (b) Herd size for goat ecotype in each season sampled (values are mean ± SE).

511 Tables

512

513 Table 1. Spearman correlation values of the proportion of time devoted to four

514 different behaviours

515

516 Table 2. Results of MANOVA explaining the effects of season, sex class, and

517 ecotype on behaviour frequencies and proportions (F approximate value, degrees of

518 freedom and P-value are reported).

519

520

Table

Table 1.

Activity	Feeding	Walking	Watching
Walking	-0.4224***		
Watching	-0.6189***	0.1761*	
Resting	-0.4803***	-0.2549**	0.0698*

*P>0.05; ** P<0.01; *** P< 0.0001

Table 2.

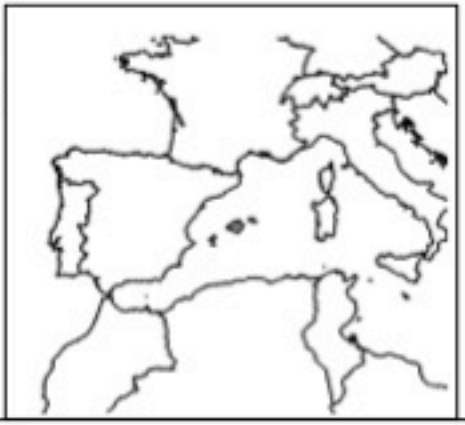
MANOVA

Effect	**Approx. F**	**df* 1**	**df2**	*P*
Proportions				
season	3.01	5	129	0.01
ecotype	0.76	5	128	0.58
sex	0.92	5	128	0.45
season*ecotype	3.14	5	129	0.01
season*sex	1.66	5	129	0.15
ecotype*sex	0.62	5	128	0.68
season*ecotype*sex	0.19	5	129	0.48
Frequency				
season	4.99	5	129	<0.001
ecotype	0.67	5	128	0.65
sex	0.58	5	128	0.71
season*ecotype	2.92	5	129	0.01
season*sex	1.49	5	129	0.18
ecotype*sex	1.21	5	128	0.3
season*ecotype*sex	0.91	5	129	0.48

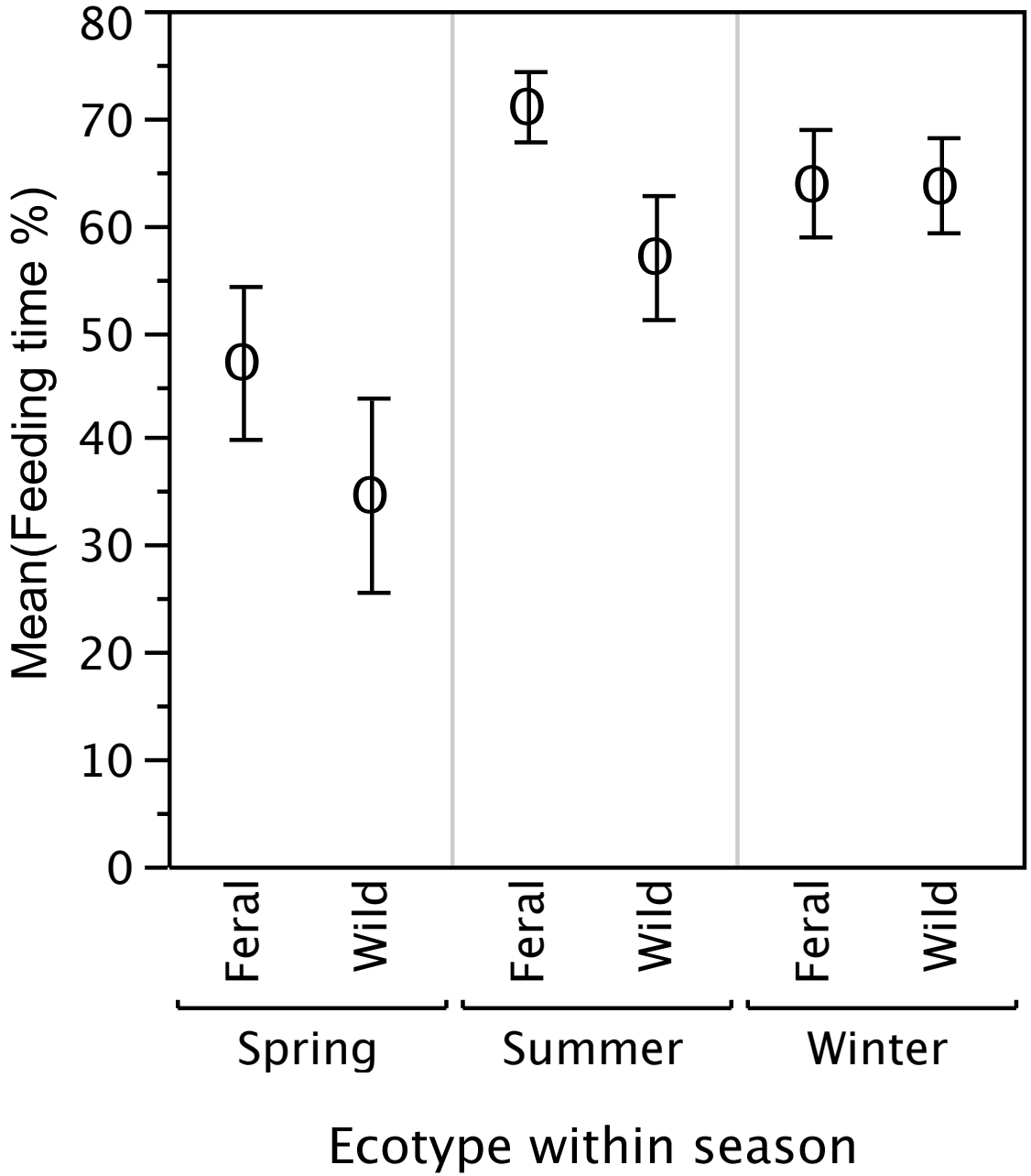
* df = Degrees of freedom

Figure

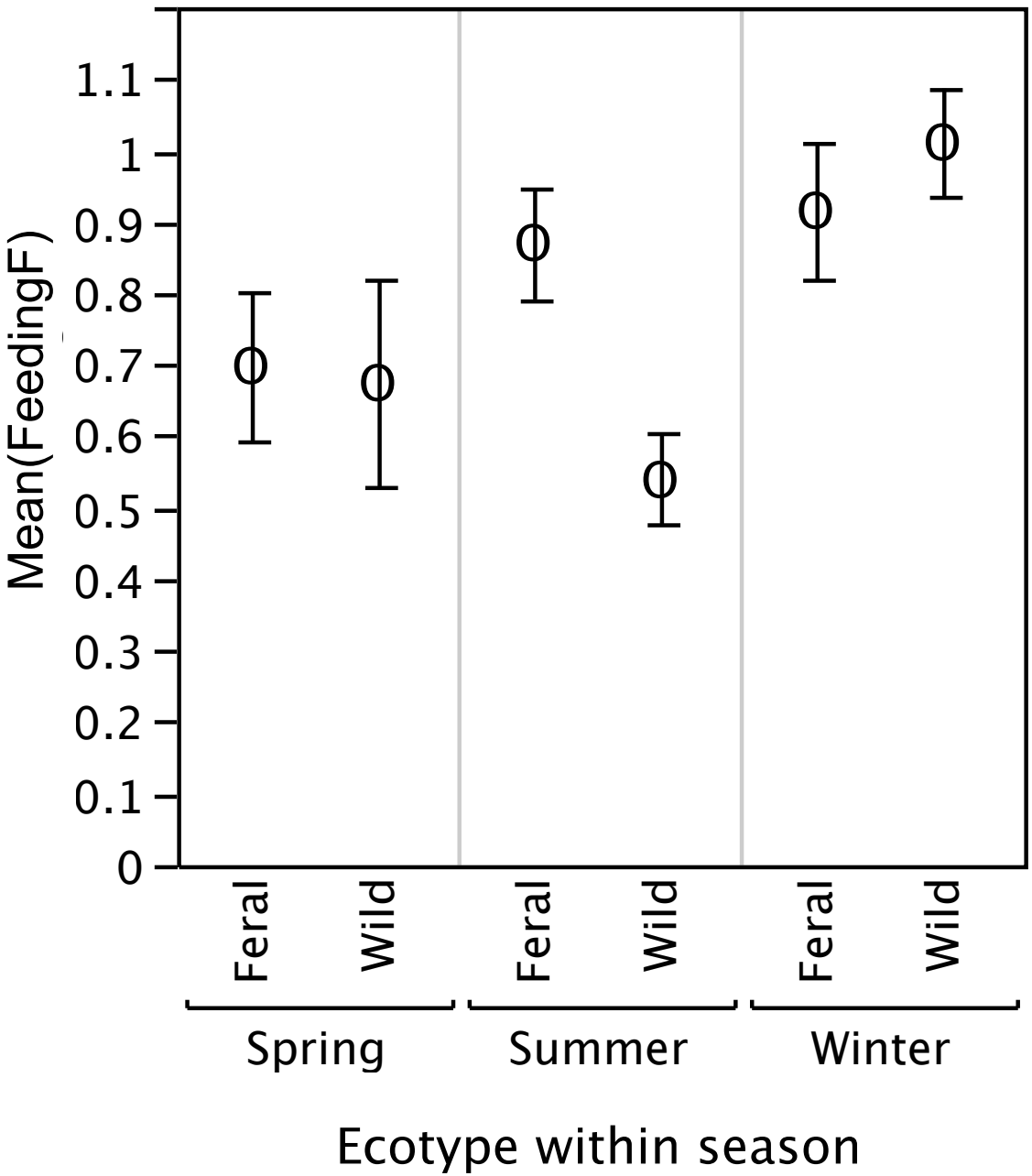
Area name	Location	Altitude (m a.s.l.)	Stocking rate (head/ha)
1.-Trapa	39º36,044" N 002º21,543"E	258-373	0.77
2.-Sant Vicenç	39º55,540" N 003º 03,122"E	77	0.25
3.-Formentor	39º56,997" N 003º09,633"E	147	0.33
4.-Victoria	39º51,860" N 003º09,694"E	89	0.65



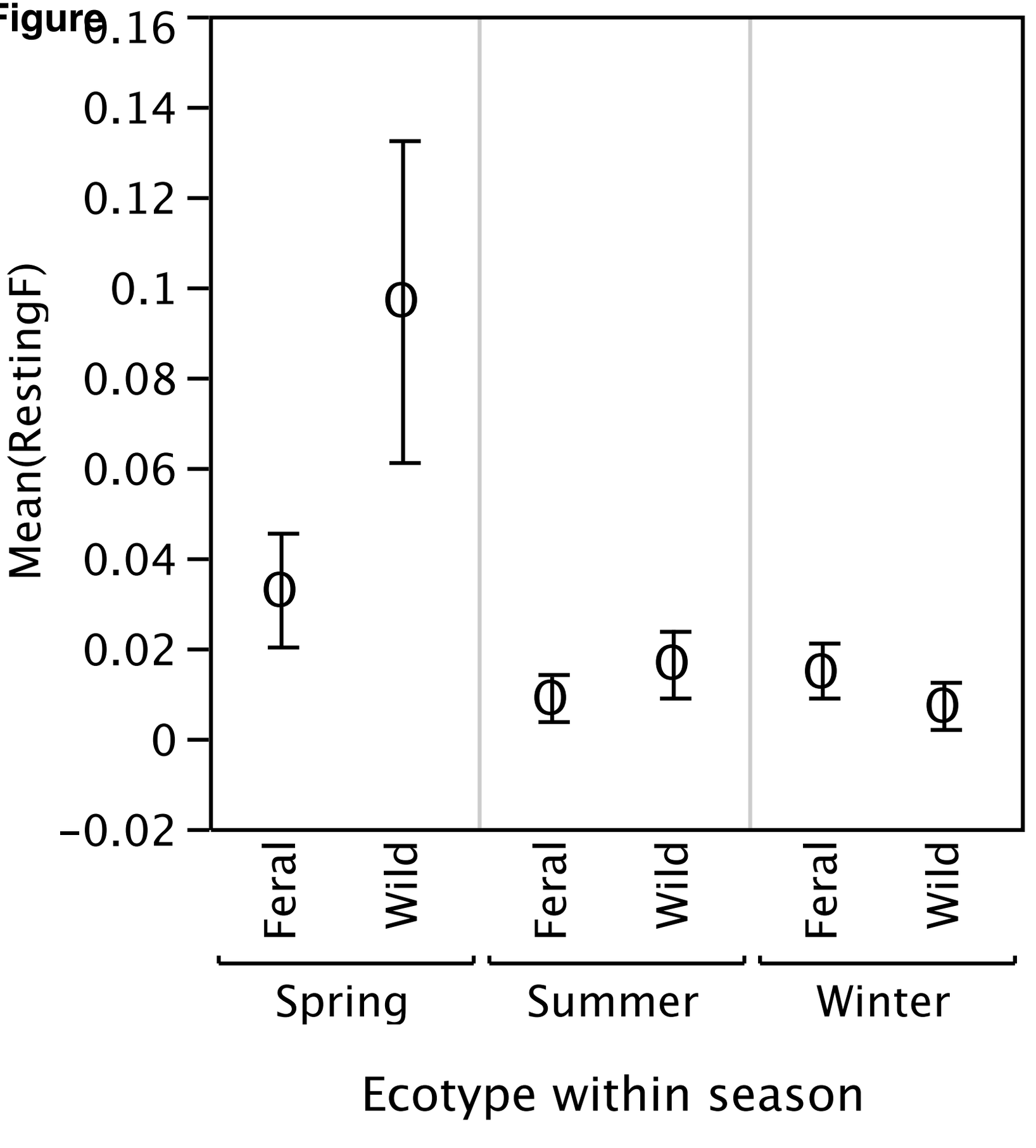
Figure


80
70
60
50
40
30
20
10
0
Mean(Feeding time %)
Feral
Wild
Feral
Wild
Feral
Wild
Spring
Summer
Winter
Ecotype within season

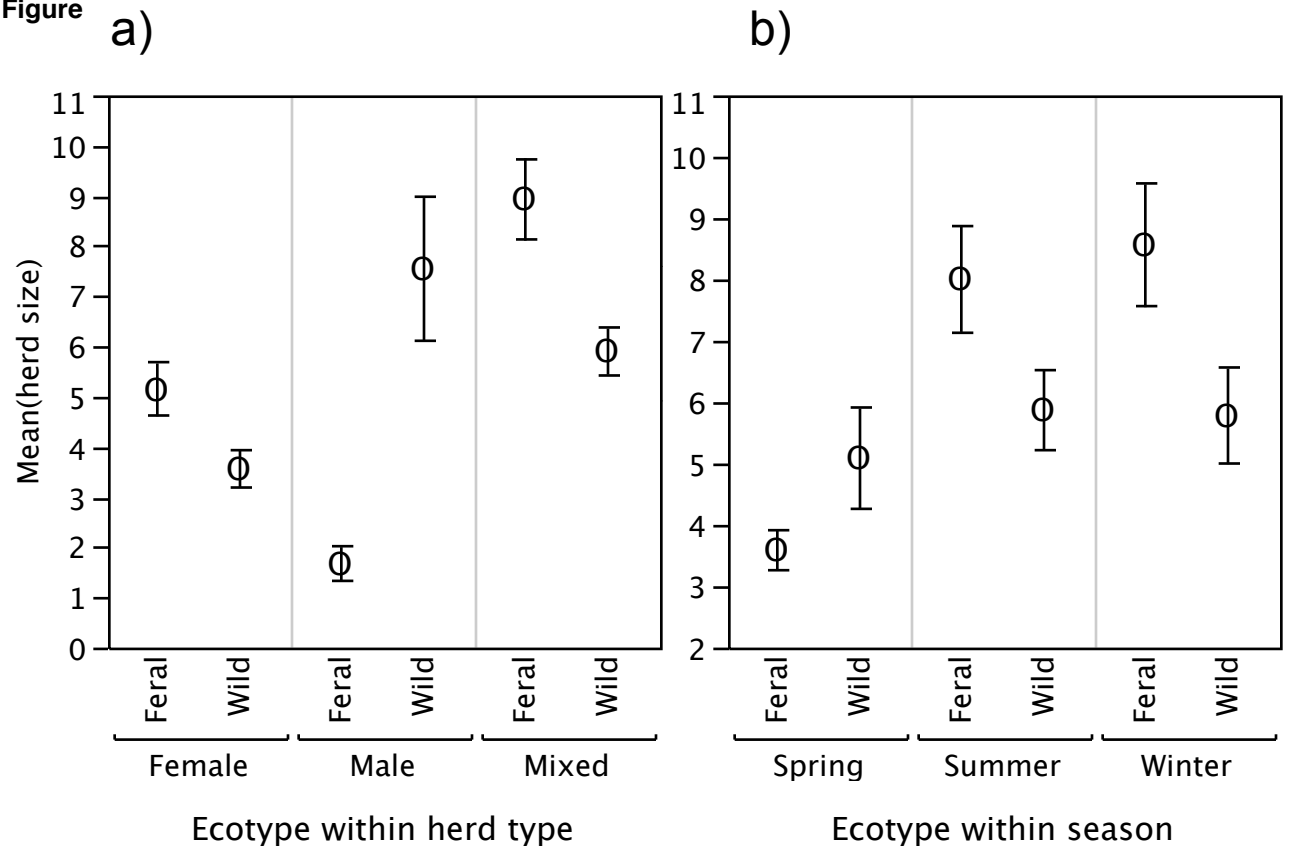
Figure


Mean(FeedingF)
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Feral
Wild
Feral
Wild
Feral
Wild
Spring
Summer
Winter
Ecotype within season

Figure


0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
−0.02
Mean(RestingF)
Feral
Wild
Feral
Wild
Feral
Wild
Spring
Summer
Winter
Ecotype within season

Figure


a)
b)
Mean(herd size)
11
10
9
8
7
6
5
4
3
2
1
0
Feral
Wild
Female
Male
Mixed
Ecotype within herd type
Spring
Summer
Winter
Ecotype within season